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No. 736,288



June 14, 1966 **ISSUED** CLASS

GROUP

CLASSIFICATION

## CANADIAN PATENT

LINER EXPANDER

Joe C. Stall, Tulsa, Oklahoma, U.S.A.

Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

APPLICATION No. 897, 460

PRIORITY DATE

No. OF CLAIMS

#### LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

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Since tools of the type mentioned above often are cmployed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial cectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the vall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the vall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential sorew element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lover bearing plate member 46 contacts the lover ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

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A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various coppor base alloys, such 10 as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft lo.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 rounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein  $P_{c}$  is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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#### I CLAIM:

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- 1. A device for expanding a metallic liner inside a conduit which 1 2 device comprises a shaft element, an expanding die member attached to said 3 shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to 5 contact said liner, an expander member slidably positioned on said shaft 6 between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft 8 to contact said expander member and to maintain said expander member against 9 said liner-forming member, whereby said liner-forming member is urged against 10 said liner by a substantially constant force.
  - 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
  - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
  2 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a

  sleeve-like element connected to said movable bearing plate member and

  slidably positioned on said shaft and a member connected to said shaft to

  limit the travel of said sleeve-like element.
  - 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said chaft.
  - 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

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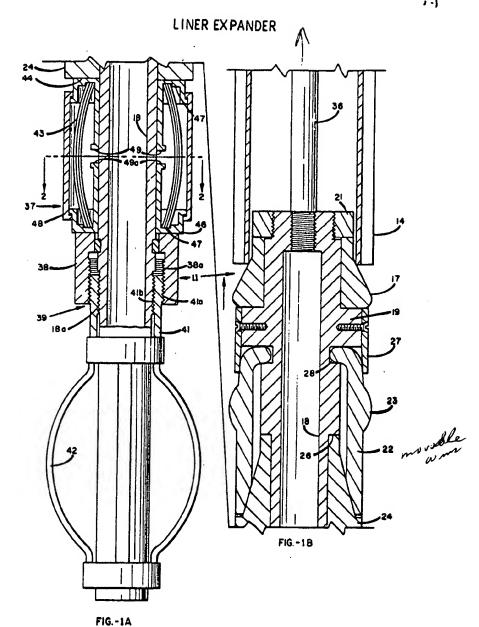
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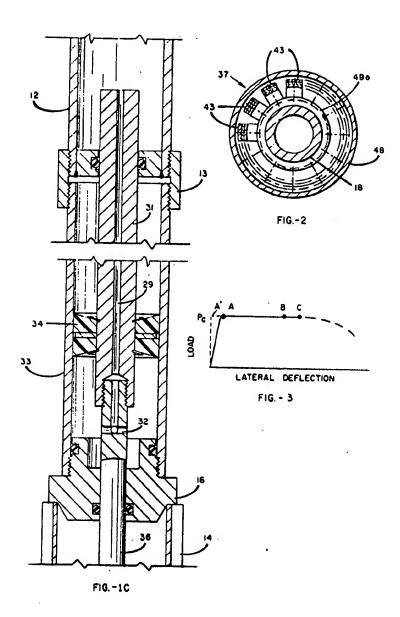
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E. In a device for installing an expended metallic liner in a combit's wherein an expending die is moved through a liner positional in said sondain to expend said liner; a cylindrical staff almost, an expending die meeder attached to said shaft, said die newbor comprising a plurality of any meeders disposed around said shaft and being pivotable intervity therefore to contact stid liner, a cons member alidably positioned on said shaft between said shaft and members to very said are members consequely from said staff, and a constant force gring member positioned on said staff to contact stid cone member and to maintain said come member in contact with said are members, whereby said age tembers are urged outpartly by a substantially constant force.

J. The fewice of Claim 2 shareds shid constant force opting ansher comprises a plumility of columns disposed around exid shaft, a filest boaring plate number and a second bearing plate number, canh of said bearing plate members contacting opposite case of said columns, at least one of said bearing plate numbers being coverably positioned on said shaft and being in contact with said come number, stop means commerted to said shaft to limit the exial travel of said mostable bearing plate number along said shaft, and compression memors for maintaining a lateral defication in said columns.

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- . A. The device of Claim 3 wherein said compression group comprises a differential survey equantity mid apring number and said shaft.
- 5. The device of Claim 3 wherein said step means emprises a slare-like element commented to said soveble bearing place number and stimular positioned on said shaft and a sunfox commuted to eaid shaft to limit the travel of said slare-like element.
- 6. The dovice of thats 3 whereis soil columns have a meaning arous-scotion, the width being greater than the thickness, and bearing the mider face moved to the dissource of said shaft.
- 7. A device for installing on expended metallic liner to a cominit taich comprises a cylindrical shaft clustri; on separating the senter numbel on said shaft, said the senter comprising a plantity of are spekara disposed cirmsfareshially around the ombride of said shaft and budge pluotable outearly therefrom to contact the liner; a scaled augusting master slidely hies agree of traducts are him bos flads hims count of thads hims no be are members outsumout from suid shaft; a planelity of element columns, each baving a long reutangular occes-sertion and disposed sireumbrantially should suid chaft; an upper bearing plate number and a lower bearing plate suffer; sech slidsly positioned on said shaft and contacting opposite onds of said columns limiting alserves whiched to each of soid bearing plate numbers and alidably positioned an said statt; a shoulder number on said shaft; a differential sever element connecting sets shoulder and said shock to apply skiling look to said columns said thoulder being companies with the limiting misers immeded to said leaver bearing plate mester, wherety the arial trevel of each bearing plate members in limited; said column washers branesicking their buckling look to exid arm nembers to urgs said arm greaters extendity with a substantially communication.

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#### LITER EXPANSES

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Birnituture, a mathod and apparatus have been developed for installing on expenses existing times as an asl well or other operation. typically, a conveyated about liner is immerted in a conduct which is in he hims, the greatest periphosal-dissection at the liner being elighbly less became at Loub patheneque at . State or the contest and appending tool is person through the liner placed in the ambuit, and a first-stone expending disgroup plantic documention of the liner, which is againsed outwardly against the fraids of the southits. A season-stage die on the tool than provides on additional finer defendation of the lines to provide a smoother re finished surpose on the isside of the liner and to wasure some complete contact between the conduct and the liner. In a typical design of this type espending tool, the frictional drag of the first-stage die sugnises the expanding force for the second-stage dio, which expanding freet is a direct function of the strength, or wall thickness, of the conduit is which the lines is being installed. For example, in limits oil well caring, heavy well sering may sense a very high trintional force which results in excessive boding pagedred to push the expender through the limer. The application of the greet forces required my result in replace of the casing er in breaking the investiing tool. In fasteness there the internal sher of the configit is nomental lane than that extinguish, the resultas sem ecuse the tank to become account in the casing, or otherwise uge to the exains and the tool. In other dealgas, such as there a quantilerent spring arrongment in employed in econsystem of in the secondstigs die, various difficulties are encountered in obtaining a spring aion beving the desired stroughb in continuation with the other spring characteristics, and with the tool dragging against the incide well of the which after boths passed through the liner.

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conduct by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figure 14, 18 and 10, tabes together, convitute a partial sectional view of a preferred embediment of a liner expending tool according to

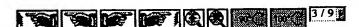




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Figure ) is a typical plot of applied look versus deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 14 is the lotton portion of a liner expending tool for one in installing a metallic liner in a well, while Figure 13 silmetrates the middle section of such a tool and Figure 10 represents the upper sestion of the tool. The expending tool il is ablanted to ctanders well taking 18 by compling 15 ons, typically, may be lowered from the sorrase through a woll ensing (not shown) to a point in the soring at which it is sesired to invivit a metallic liner. Butter inserting the test into the well, an alongsted vertically corrugated liner in Cabricated from mild steel, or other suitable mileshie unterfal, is placed on the tool. The corrupted liner is secured in position by contact at its upper end with a cylindrical ther 16 and, at the lower and by contact with a first-stage expansienting die in the seveer hereinefter described. The expanding die is fixedly edtached to a controlly located, elongated cylindrical hollow shaft ld which forms a portion of the body of the tool. As shown, the expending size 17is half in place between a lower shoulder 19 and coller 21 threaded onto the shaft. A plurality of accepble arms 89, preservably provided with outsardly salarged portions 25 sear the top; are disposed in the form of a sylinter ad abut's 16. The unlarged purbless of the some 23 upon being moved outvarily corriect the liner to purform the final step of expending the corregated liner into a substantially splintrical shape. The are eashers HE are pivotally etteched to the sheft so as to be movehile unbestily from the sheft by a tapared expending member 26 slikebly positioned on the sheft to serve as a second-stage expender. The surface of the master Db, as shown, moves spendly along the chaft to engage with the arms and more than outvertily. Advantageously, the 30 inside surfaces of the area 22 and the outside confuce of expanding seeder 25 form setting sentions, typically cotegonal is shape. The expension of the arm members is comiralled by the position of the member 34 raich moves openedly



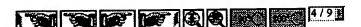


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until) it contacts obsolder his provided on the claft. As number it moves in a documently direction eras his fall invertily toward the shaft. The expecting arms 22 are build to place on the shaft by collect 27 and circular grooms 20

The expecting tool, comprising the first-stage die and the secondstage die is dress through the limit to expend it is place in the casing. The first-stage die provides a gross deformation of the liner so that it is expended convextly against the wall of the eming. The second-stage die then passes through the liner and perform the final expension to exceed the inner surface of the liner and to provide more even contact between the liner and the wall of the centur and effect a finid-tight scal.

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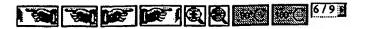


forces between the tool and the liner and the presence emerted against the oneing are extended at predatorsized safe levels. The comment force spring maker ensures that the context presence between the liner forming pursue 25 of the arms 22 is great ecough to provide the desired deformation of the neaing, while preventing desage to the ensing or to the tool.

The especial force spring stanter 77 is aligned; so countried on the about 18 and between the expending alasant 28 and a cylindrical lower choolder senter 36 forcing a portion of a differential server alasant 39 which transmits the lower senter price shaft number 16 as the cotride of which are one sate transfe life, the lower shaller master 16 as the cotride of which are one sate transfe life, the lower shaller master 16 as the cotride of which are one sate transfe life, the lower shaller master 18 provided with female threads 55 and thinkle master 51 provided with threads 51 and thinkle life, the lower shall with threads 51 and thinkle and 51 as the cotride and the matter, respectively, to suggest the sate of threads are source, such as square, undiffici square, or home through, to witherent very high loads and differ in pitch so that shoulder 15 is seven upwarfly on the shaft 18 when the shaft 15 by splines 57 so that 11 can alide longitudinally, but it is not tree to robute on the shaft. Finally attached to the lower and of the thinkle is a stiction newher, such as how aprings 18, a hydralically setuated friction pas, or other such device for frictionally employed; with the inside wall of the analysis occurs the thinkle against rotation with respect to the shaft. Preferably, the direction of the shoulder sames threads 15a to the same as that of the shaft threads 15a, e.g. right-bend threads 15a to the same as that of the shaft threads 15a, e.g. right-bend threads 15a, in the pitch, or lead, of streads 15a is slightly greater time shoulder sames 35 to advance upward alightly and a compression load is americal suparried; on appring element 37 to assect building. For example, one writeratory threads on a obsert approximately 1.7-inch outside diameter and five and increase threads on a obsert approximately 1.7-inch outside diameter and five and increase.



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A means for limiting the defination of the columns is required.

Although the column element functions in a backled condition, application of stressive measures lead thereto would sense total failure or repture of the column. Therefore, a pair of stope h9 and 85a are provided for this purpose. As shown, the stope are rigidly commerced to the bearing plairs, and, in affect comprise upper and knew limiting slavers positioned on the shelf to alide longitudinally thereon. The ends of the stope may move toward, or may from, each other me the load on the spring number worder. Lover slaver his is prevented from moding from by loads shoulder 35 assessed to the other 15. However, the spacing between the male is much as to limit the longitudinal travel of the bearing plate manders as they move together to prevent persecuting damage to the column almosts 53. Written alternative manns for preventing samage to the column almosts 53. Written alternative manns for preventing someted on this chaft may serve as atops, or the cover 48 provides with extinable communical methods for columns.

The columns of the column classes 45 may be arranged around the coart 16, which as shown here forces a partion of the body of the spring device, with ends of the columns fitted in the races 57. The columns may be

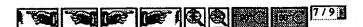
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ritied closely tognihur as shows, or may be spaced around the race, with separators used between them to meisteds the desired spacing. The runker of construction for enumple, the elementary ratio of the column may be varied within, say the column may be varied within, say the column may be varied. The preserved construction is a thin, element column with remarked ands, from to now within the recess shaped to the column and to column and in the recess shaped to the column at the column and in alloy stands, chronically employed for the column are column and ion alloy stands, chronical satisfactory mathematical properties. Appearing the individual columns are or long recessions, the high stabel alloys and other similar materials providing satisfactory mathematical properties. Typically, the individual columns are or long recessional cross-contion, with the width being greater than the lakehouse, and arranged so that the wider face of the unisme is normal to the simular of the shart. Thus, with surfacient compensation loading, the columns backles, and tend shout the arise having the loars security or inertia, e.g., outwardly may from the shart 18.

For example, a group of columns 0.167-inch thick by 0.438-inch wife by 10.626-inches long, with the ends rousest, were februared from A.f.S.I 4360 steel, quenched and drawn at 575°F. Buth column was found to require a critical compression leading or 160 pounds in order to bunkle the calumn. . After bunkling, the columns were found to have a very flat spring characteristio, as shown in Figure J, thereis Po is the critical beaking load set point serie the load and deflection at which the stress in the exhaus fibers alumn exceed the yield yount of the untertal. Theoretically, the shape of this spring obsesseristic ourse is described by ourse CA'ABC. Annually, this curve is described by OASC due to friction in the system. Potote A and B ent typical straing limits, which, of course, may be varied according to the application for which the spring to designed. For example, where a h ber of Thuring epoles are not unticipated, a working strass just below the 50 yield point may be used, while with a great number of flexures, the working so may be held to less than the enformes limit of the seterial of some tion. In the above-municipal tests, the intered derication was limited to





approximately one tree, at which the longitudinal deflortion was approximately 0.825 inches. From more deflection to the assistan deflection, the 450-pound loading was found to be substantially constant.

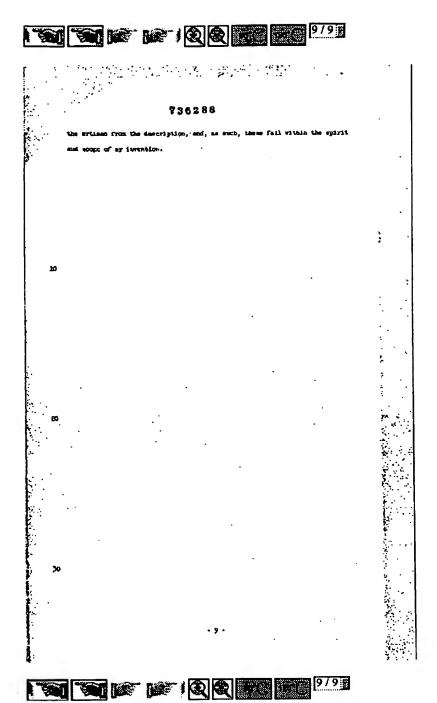
In emother test a spring device was built, as shown, employing 80 columns, each having a critical buckling load of 1250 younds. The interal declaration was limited between 0 and about 1.00 inches by suprogrately positioning the stope. Once compressional loading, the spring element buckled at eductorically 25,000 pounds and from a longitudinal deflection of 0.06 inshes (making) to stook 0.15 inches the load remarked substantially at 25,000 pounds.

Of course, in conjusing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of laboral deflection and critical bubling load, while unintending the airest level to the columns at a safe isval. The preferred columns, therefore, are laminated, as shown in Figures 12 and 2, with mittiple flat emplors units on seath columns.

In the operation of the shows expending tool for setting a liner in well section, the made-up tool is lovered into the sell us sectioned shows, with the ares 22 in the retreated position. Shen the tool is at the desired level, the well taking is revolved. The friction member by transpare with the wall of the sexing and prevents thinble b) from revolving. With several revolutions of the taking, lower shoulder 35 is novel againstly by differential server 39 to bushle spring alasmed 37 which has a predefermined writional buckling loss. This less is transmitted assembly against the lower and of expender the, and the tapered surface is engaged with the tapered surface on the issues of the erms at to args the losse outwardly with a substantially constant force proportional to the critical buckling loss of the spring element. Subsequently, the expending tool is passed through the lines to expend it in the casing in the memor described hereisbefore.

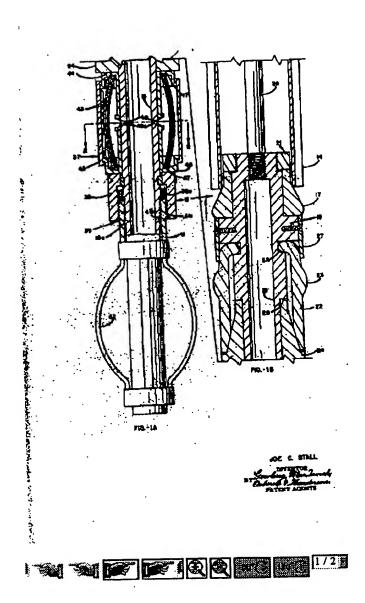
The foregring description of a preferred embediesst of sy investigation has been given for the purpose of examplification. It will be understood that various medifications is the detects of assertantion will become apparent to

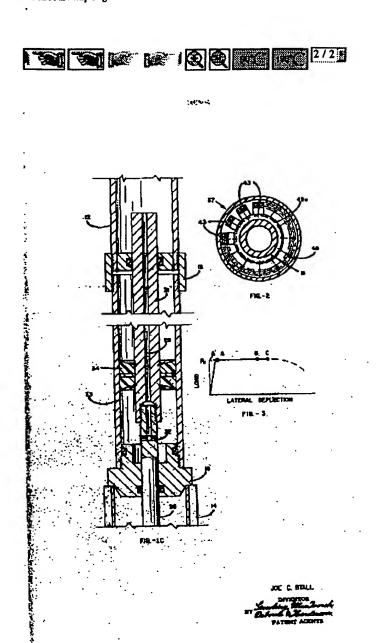
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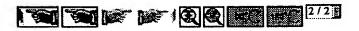




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